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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B25J 21/00, H02K 16/00 — A1

(11) International Publication Number: WO 94/23911

(43) International Publication Date: 27 October 1994 (27.10.94)

(21) International Application Number: PCT/US94/04040

(22) International Filing Date: 13 April 1994 (13.04.94)

(30) Priority Data:
08/048,833 16 April 1993 (16.04.93) US

(81) Designated States: CN, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

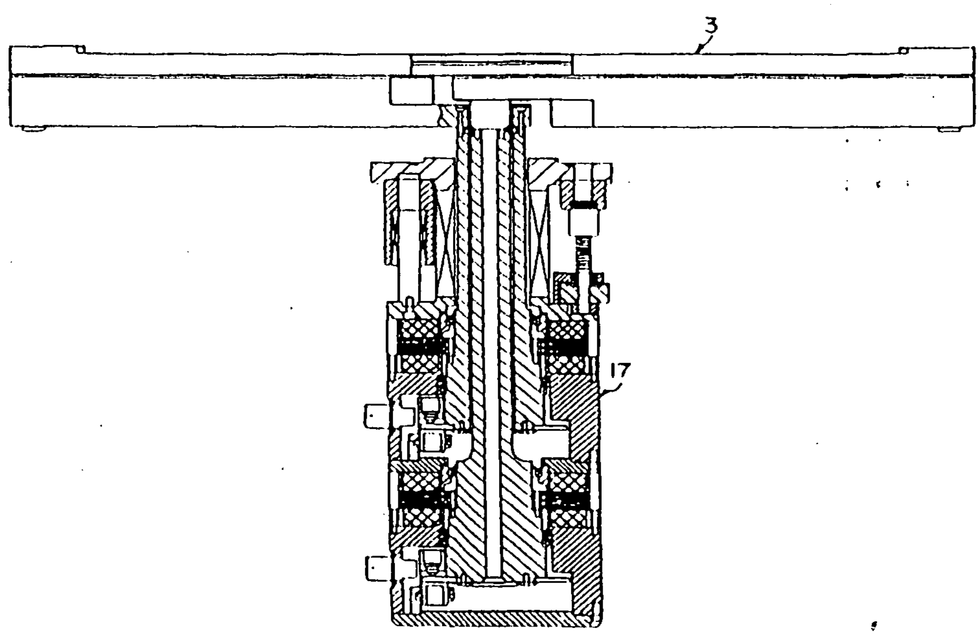
Published
With international search report.

(71) Applicant: BROOKS AUTOMATION, INC. [US/US]; 41 Wellman Street, Lowell, MA 01851 (US).

(72) Inventor: HOFMEISTER, Christopher; 176 Wheelwright Road, Hampstead, NH 03841 (US).

(74) Agent: NIELDS, Henry, C.; Nields & Lemack, Suite 8, 176 E. Main Street, Westboro, MA 01581 (US).

(54) Title: ARTICULATED ARM TRANSFER DEVICE



(57) Abstract

A concentric-shaft rotational drive system for an articulated arm transfer device (3) adaptable for imparting movement to an assembly inside a vaccuum chamber (2) wherein rotary movement is imparted to rotors (7, 9) inside the vaccum chamber (2) by means of magnetic fields produced by stators (8, 10) outside the vaccum chamber.

ARTICULATED ARM TRANSFER DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The apparatus of the present invention relates generally to material transfer devices. The material transferred might include, but not be limited to, semiconductor wafers, such as Silicon and Gallium Arsenide, semiconductor packaging substrates, such as High Density Interconnects, semiconductor manufacturing process imaging plates, such as masks or reticles, and large area display panels, such as Active Matrix LCD substrates.

2. Description of the Prior Art

The transfer of delicate silicon wafers or the like between a plurality of work stations or locations in the manufacture of semiconductor devices presents unique handling problems. The silicon wafers are very delicate and have highly polished surfaces. When the wafers are abruptly moved, they tend to slide. This sliding action can cause the silicon wafers to abrade or alternatively can cause damage to their edges if they collide.

There are numerous devices described in the prior art for transferring silicon wafers. For example:

U.S. Patent No. 3,823,836 discloses an apparatus which includes a supply carrier with a plurality of ledges to hold the silicon wafers and a withdrawal device having a vacuum chuck. The vacuum chuck is attached to an elevator which raises and lowers the chuck. A horizontal transfer arm coupled to the vacuum chuck is used to transfer the silicon wafer from the supply carrier to a desired work station.

U.S. Patent No. 3,370,595 discloses a wafer transfer handling apparatus having an indexable carrier for transferring wafers to and from work stations. Wafers enter and leave the wafer carrier on an air slide with the aid of

a wafer ejector acceptor arm having directional air jets. The wafer ejector acceptor arm controls the driving of the wafers into or out of the carrier from or onto the air slide, which moves the wafers to or from a work station.

U.S. Patent Nos. 4,062,463, 3,874,525 and 4,028,159 also disclose wafer transfer devices which include either pneumatic components or gripping devices for handling the wafers.

U.S. Patent Nos. 4,666,366 and 4,909,701 disclose wafer transfer handling apparatus having an articulated arm assembly which extends and retracts in a "froglike" motion to transfer an object such as a wafer between a plurality of locations. Two articulated arms are operatively coupled such that when one arm is driven by a motor the articulated arms extend and retract in a "froglike" or "frogkick" type of motion. A platform is coupled to the arms and has the object to be transferred disposed thereon.

U.S. Patent No. 4,951,601 discloses wafer transfer handling apparatus having an articulated arm assembly which includes a concentric-shaft, rotational drive system. However, such drive system requires rotary seals which can contaminate the vacuum chamber. In the drive system of U.S. Patent No. 4,951,601 the inner shaft 98 is mounted on a drum 111 which is rotated by a cable 113 mounted on a drive 115 which is rotated by a belt. It appears that the drive 115 rotates in an aperture in the vacuum chamber, thus requiring a rotary seal. The hollow middle shaft 96 is mounted on a drum 101 which is rotated by a cable 103 mounted on a drive 100 which is rotated by a belt. It is not clear which components are inside the vacuum, but it seems clear that some rotating member must rotate in an aperture in the vacuum chamber, thus requiring a rotary seal. The device of the present invention has no such rotary seals. All bearings of the present invention are entirely within the vacuum, and all rotating parts are entirely within the vacuum.

SUMMARY OF THE INVENTION

The present invention provides a concentric-shaft rotational drive system for an articulated arm transfer device adapted to transfer objects, such as silicon wafers, camera lenses, crystal oscillators, or the like, between a plurality of locations disposed in various axial and radial planes.

The drive system permits the entire articulated arm assembly to be rotated in a radial plane. Like the apparatus of the prior art, such rotation is done when the end effector is not in an extended position.

The drive system also permits the platform assembly to be displaced in an axial direction. The assembly is adaptable for use in a variety of environments, including operation in a vacuum chamber or other controlled environment. The assembly may be mounted for movement inside a vacuum chamber with a vacuum seal between the assembly and its support.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a central section through a dual-shaft device constructed in accordance with the invention and connected so as to drive an articulated arm transfer device of the type disclosed in U.S. patent No. 5,180,276 to Hendrickson and assigned to the assignee of the instant application;

Figure 2 is a detail of a portion of the central section of Figure 1;

Figure 3 is a detail of a portion of the central section of Figure 2;

Figure 4 is a plan view of the device of Figure 1;

Figure 5 is an isometric sketch of a prior art device;

Figure 6 is a plan view of the device of Figure 1 but modified to drive an articulated arm transfer device of the type disclosed in co-pending application Serial No. 997,773 filed December 28, 1992 by Eastman and Davis and assigned to the assignee of the present application;

Figure 7 is a central section along the line 7-7 of Figure 6; and

Figure 8 is a central section similar to that of Figure 1 and showing another embodiment of the invention in which a single motor and two brakes are employed.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figures 1 through 4, a mounting flange 1 is attached to an apertured region of the bottom wall 2 of a vacuum chamber within which an articulated arm transfer device 3 is supported. The mounting flange itself has a central aperture through which two concentric output shafts extend. The outer shaft is designated 4, and the inner shaft is designated 5. At the extremities of the output shafts within the vacuum chamber a pilot bearing 6 separates the shafts and supports them upon each other. The two shafts are independently rotatable. However, in the preferred embodiment of the invention the relative motion of the shafts is limited to one in which they rotate together, and another in which they rotate in opposite directions. The former motion serves to rotate the articulated arm transfer device, and the latter motion serves to extend and retract the articulated arm transfer device.

The inner shaft is longer than the outer shaft, and the extremity of the inner shaft outside the vacuum chamber extends beyond the corresponding extremity of the outer shaft and attains a maximum outer diameter corresponding to that of the outer shaft. A rotor 7 is supported on the outer surface of the outer shaft 4, and a corresponding stator 8 is supported outside the rotor 7. Similarly, a rotor 9 is supported on the outer surface of the inner shaft 5, and a corresponding stator 10 is supported outside the rotor 9. Each stator is part of a drive which rotates the corresponding shaft. As appears hereinafter, each rotor is inside the vacuum and each stator is outside the vacuum.

Each rotor-stator pair 7,8 and 9,10 may form part of a conventional brushless DC motor such as the M & K Series manufactured by MFM Technology, Inc., 200 Thirteenth Avenue, Ronkonkoma, New York 11779.

Rotary motion is imparted to each shaft by well-known servomechanism techniques, wherein a suitable signal is applied to the coils of the stators.

The varying position of each shaft as it rotates is detected by a suitable sensing mechanism in combination which a suitable coded disk or the like. For example, a coded pattern of opaque portions on a transparent disk may be caused to pass between a light source and a light detector. In lieu of such an optical sensing mechanism, a magnetic sensing mechanism may be employed wherein a coded pattern of magnetized portions on a magnetic disk may be magnetically scanned. Alternatively, the sensing mechanism may be mechanical, such as a combination of a gear and a switch, or it may be acoustical, with rotation of each shaft producing coded clicks of some sort; even electrostatic systems may be designed. For purposes of illlustration, and without limiting the scope of the invention thereto, an optical sensing mechanism will now be described.

A disk 11 is affixed to the outer extremity of the outer shaft 4 by a clamp plate 12. This disk has a coded pattern of opaque portions which pass between a light-emitting-diode housing 13 and a read head 14, from which a signal is transmitted to the appropriate external circuit through a signal feedthrough 15. The light-emitting-diode housing 13, the read head 14, and the signal feedthrough 15 are supported on a drive housing 16 which is fixed and forms part of a vacuum-tight tubular casing 17. The rotor 7 is affixed to the outer shaft 4, and the stator 8 is affixed to the drive housing 16 by a stator clamp 18, positioned so that the stator 8 can co-act with the rotor 7; and two bearings 19, 20 are provided between the outer shaft 4 and the corresponding drive housing 16 upon which that drive is mounted. Similarly, a disk 31 is affixed to the outer extremity of the inner shaft 5 by a clamp plate 32. This disk has a coded pattern of opaque portions which pass between a light-emitting-diode housing 33 and a read head 34, from which a signal is transmitted to the appropriate external circuit through a

signal feedthrough 35. The rotor 9 is affixed to the inner shaft 5, and the stator 10 is affixed to the drive housing 36 by a stator clamp 37, positioned so that the stator 10 can co-act with the rotor 9; and two bearings 38, 39 are provided between the inner shaft 5 and the corresponding drive housing 36 upon which that drive is mounted.

The drive housings 16, 36 are of special configuration, and provide an important part of the vacuum-tight casing 17 which separates the evacuated regions of the device from the atmospheric-air regions of the device. The two drive housings are similar in shape and are connected to each other by an adapter 40.

Vertical motion may be imparted to the shafts by vertical movement of the drive housings which in turn are supported on two linear slides 41 and two lead screws 42. Alternates to the lead screws with rotary motors may be linear motors (servo or stepper) or a voice-coil or solenoid. The vertically movable drive housings are separated from the mounting flange by suitable bellows 43, and the outer extremity of the outermost drive housing is closed off by an end cap 44. Thus the entire region within the bellows, drive housings and end cap may be evacuated, and frictional motion inside this evacuated region is limited to that of the various bearings.

Each drive housing has a portion which passes between its respective rotor and stator, and sufficient clearance must be provided between the rotor and this part of the drive housing.

A prior art device is shown in Figure 5. Rotary motion is imparted to the articulated arm transfer device by rotating the rotate plug. Extension and retraction of the frog-legs is achieved by counter-rotation of the extend/retract drive shafts. The structure of the present invention reduces the number and type of seals required by the use of concentric shafts constructed in a particular way. The prior-art device shows that control may be effected by (1) simple rotation of a shaft and (2) counter-rotation of two shafts. In the device of the invention, (1) is provided when the concentric shafts rotate together and (2) is provided when the concentric shafts

counter-rotate. In this device rotary motion is not limited by the basic mechanism, but may continue in either direction for any desired angle.

The three motions (vertical, rotary and extend/retract) may be simultaneously activated to provide any desired trajectory of the end effector. On the other hand, in some applications all three motions may not necessarily be activated, and the scope of the invention includes devices in which only one or two of the aforementioned three motions are activated.

Referring now to Figure 4 in conjunction with Figures 1-3, the outer shaft 4 is connected to one upper arm 51 and the inner shaft 5 is connected to the other upper arm 52 of an articulated arm transfer device such as that shown in the aforementioned U.S. patent No. 5,180,276. For θ motion (i.e. rotation of the end effectors 53) both rotors 7, 9 turn in synchronism in one direction. For R motion (i.e. extension and retraction of the end effectors 53) each rotor 7, 9 mirrors the other with equal but opposite rotation. These motions are computer controlled, using inputs from the two encoders.

When rotors 7, 9 turn in synchronism in one direction, shafts 4, 5 also turn in that direction. Referring to Figure 4, if the shafts 4, 5 turn clockwise, the upper arms 51, 52 also turn clockwise, along with the rest of the apparatus shown in Figure 4. Conversely, if the shafts 4, 5 turn counterclockwise, the entire apparatus shown in Figure 4 turns counterclockwise. If, on the other hand, the outer shaft 4 turns clockwise while the inner shaft 5 turns counterclockwise, the upper arm 51 will turn clockwise and the upper arm 52 will turn counterclockwise. The resulting movement of both end effectors 53 is downward in Figure 4. Conversely, if the outer shaft 4 turns counterclockwise while the inner shaft 5 turns clockwise, the upper arm 51 will turn counterclockwise and the upper arm 52 will turn clockwise. The resulting movement of both end effectors 53 is upward in Figure 4.

Referring now to Figures 6 and 7, the outer shaft 4 has affixed thereto a block 54 in which the upper slave arm 55 of an articulated arm transfer device such as that shown in the aforementioned co-pending application Serial No. 997,773 is rotatably supported. The upper drive arm 56 of such an articulated arm transfer device is affixed to the inner shaft 5 so as to rotate therewith. In this case the two shafts rotate in synchronism for θ motion, but the outer shaft 4 is held fixed and only the inner shaft 5 is rotated for radial motion.

If an articulated arm transfer device of the type shown in the aforementioned U.S. Patents Nos. 4,666,366 and 4,909,701 (such as shown in Figure 5) is made with two concentric shafts, an outer shaft to rotate the arms in θ motion and an inner shaft to generate extend/retract motion, it is possible to rotate the appropriate shaft combinations with one motor (and encoder) by using two brakes, one of which will lock the inner shaft to the outer shaft, and the other the outer shaft to the casing.

If the outer shaft is locked to the casing, and the shoulder assembly is mounted on the outer (rotate) shaft, no rotation of the shoulder will be possible. Rotation of the inner shaft by a motor attached to it will generate extend-retract motion as is now done by the extend/retract motor of an articulated arm transfer device of the type shown in Figure 5.

Conversely, if the inner shaft is locked to the outer shaft, no extend/retract motion is possible. If, therefore, the outer shaft/casing brake is released, rotation of the inner shaft by the motor will result in simultaneously rotating the outer shaft, and therefore in θ motion.

If both brakes are locked at the end of each motion, and then the appropriate brake is released, one encoder, when its signal is combined in a computer with the brake command, can indicate the motion of either parameter. If greater precision is required, two encoders, as in Figure 1 (11, 31) may be used.

By proper design and use of magnetic and non-magnetic materials, it is possible to mount all moving parts, including brake shoes and motor rotors, inside of a sealed cylindrical case, while placing the magnet coils of all components in atmosphere outside the casing. This will eliminate the known outgassing problems and electrical feedthroughs which degrade performance of systems having active electromagnets in vacuum.

While this mechanism will work with any of the extending arm assemblies typical of robots manufactured by the assignee of the instant application, a particular advantage is achieved when using the aforementioned arm shown in Figures 6 and 7 and used in articulated arm transfer devices of the type disclosed in the aforementioned co-pending application Serial No. 997,773, in that only one driving shaft is required at the shoulder, eliminating the need of gearing on top of the rotating shafts.

Referring now to Figure 8, a mounting flange 61 is attached to an apertured region of the bottom wall of a vacuum chamber within which an articulated arm transfer device 62 is supported. The articulated arm transfer device 62 is shown as being of the type shown in Figures 4 and 5. The mounting flange itself has a central aperture through which two concentric output shafts extend. The outer shaft is designated 63, and the inner shaft is designated 64. At the extremities of the output shafts within the vacuum chamber a pilot bearing 65 separates the shafts and supports them upon each other. The two shafts are independently rotatable. However, in the device of Figure 8 only one shaft is rotatably driven by a motor, and rotation of the other shaft is determined by two brakes, one of which causes the shafts to rotate together, and another of which causes the other shaft to remain fixed. The former motion serves to rotate the articulated arm transfer device, and the latter motion serves to extend and retract the articulated arm transfer device.

The inner shaft is longer than the outer shaft, and the extremity of the inner shaft outside the vacuum chamber extends beyond the corresponding extremity of the outer shaft.

A brake 66 comprising a disk 67 of magnetic material is supported on the outer surface of the outer shaft 63, and cooperates with a disk 68 of magnetic material which is slidably supported inside a casing 69 of non-magnetic, vacuum-tight material. A magnetic coil 70, when energized, magnetizes the disks 67, 68 so that they press against each other and act as a brake, preventing rotation of the outer shaft 63. Similarly, a brake 71 comprising a disk 72 of magnetic material is supported on the outer surface of the outer shaft 63, and cooperates with a disk 73 of magnetic material which is slidably supported on the inner shaft 64. A magnetic coil 74, when energized, magnetizes the disks 72, 73 so that they press against each other and act as a brake or coupling locking the shafts to each other. A motor 75, constructed similarly to the construction of rotor 9 and stator 10 of Fig. 1, serves to rotate the inner shaft 64. More specifically, a rotor 76 is supported on the outer surface of the inner shaft 64, and a corresponding stator 77 is supported outside the rotor 76. The stator 77 is part of a drive which rotates the inner shaft 64. The rotor 76 is inside the vacuum and the stator 77 is outside the vacuum.

The rotor-stator pair 76, 77 may form part of a conventional brushless DC motor such as the M & K Series manufactured by MFM Technology, Inc., 200 Thirteenth Avenue, Ronkonkoma, New York 11779.

Rotary motion is imparted to the inner shaft 64 by well-known servomechanism techniques, wherein a suitable signal is applied to the coils of the stator 77.

A disk 78 is affixed to the outer extremity of the inner shaft 64. This disk has a coded pattern of opaque portions which pass through a suitable encoder 79 (which may comprise, for example, a light-emitting-diode housing and a read head, from which a signal is transmitted to the appropriate external circuit through a signal feedthrough). The shafts 63, 64 are supported upon suitable bearings 65, 80 between the shafts 63, 64 and suitable bearings 81, 82 between the outer shaft 63 and the casing 69.

The casing 69 is of special configuration, and provides an important part of the wall which separates the evacuated regions of the device from the atmospheric-air regions of the device.

Vertical motion may be imparted to the shafts by vertical movement of the casing 69 in a manner hereinbefore described in connection with Figure 1.

The casing 69 has a portion which passes between the rotor 76 and stator 77, and sufficient clearance must be provided between the rotor 76 and the casing 69.

Having thus described the principles of the invention, together with illustrative embodiments thereof, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

I claim:

CLAIMS

1. Apparatus comprising

a vacuum enclosure having an aperture and a capped tubular member mounted over said aperture and including a first drive housing and a second drive housing;

an outer shaft mounted on and inside said first drive housing by bearings;

an inner shaft within said outer shaft and concentric therewith and mounted on and inside said second drive housing by bearings;

a first rotor mounted on said outer shaft;

a second rotor mounted on said inner shaft;

a first stator mounted on and outside said first drive housing;

a second stator mounted on and outside said second drive housing;

a pilot bearing supporting said outer shaft upon said inner shaft; and

means for causing each of said stators to impress a suitable electromagnetic field upon its respective rotor so as to impart rotary motion thereto.

2. An apparatus for transferring objects, comprising:

a support;

a first upper arm supported on said support so as to be rotatable about a first axis;

a second upper arm supported on said support so as to be rotatable about a second axis;

means for causing said second upper arm to be driven by rotation of said first upper arm;

a first pair of forearms articulated to said first and second upper arms;

a second pair of forearms articulated to said first and second upper arms;

each of said upper arms being of lesser length than each forearm;

first holding means pivotally coupled to said first pair of forearms and second holding means pivotally coupled to said second pair of forearms, an engagement between said first pair of forearms and adapted to prevent rotation of said first holding means, and an engagement between said second pair of forearms and adapted to prevent rotation of said second holding means; and

driving means capable of driving said first upper arm for rotation through an angle in the range of from greater than 120° up to and including 180° to move said first holding means between a first extended position and a first retracted position while

simultaneously moving said second holding means between a second retracted position and a second extended position; said driving means including the following components:

a vacuum enclosure having an aperture and a capped tubular member mounted over said aperture and including a first drive housing and a second drive housing;

an outer shaft mounted on and inside said first drive housing by bearings;

an inner shaft within said outer shaft and concentric therewith and mounted on and inside said second drive housing by bearings;

a first rotor mounted on said outer shaft;

a second rotor mounted on said inner shaft;

a first stator mounted on and outside said first drive housing;

a second stator mounted on and outside said second drive housing;

a pilot bearing supporting said outer shaft upon said inner shaft; and

means for causing each of said stators to impress a suitable electromagnetic field upon its respective rotor so as to impart rotary motion thereto.

3. An apparatus for transferring objects, comprising:

a support;

a first upper arm supported on said support so as to be rotatable about a first axis;

a second upper arm supported on said support so as to be rotatable about a second axis;

a pair of forearms, comprising a first forearm and a second forearm, said pair of forearms being articulated to said first and second upper arms by means of link means;

said link means comprising a link, an upper shaft rotatably supported on said link, a lower shaft rotatably supported on said link, and means for causing rotation of one shaft in one sense to cause rotation of the other shaft in the opposite sense;

said first upper arm being fixed to said upper shaft;

said second upper arm being rotatably mounted on said lower shaft;

said first forearm being fixed to said lower shaft;

said second forearm being rotatably mounted on said upper shaft;

holding means pivotally coupled to said pair of forearms; and

driving means capable of driving at least one of said upper arms for rotation through an angle in the range of from greater than 120° up to and including 180° to move said holding means between an extended position and a retracted position; said driving means including the following components:

a vacuum enclosure having an aperture and a capped tubular member mounted over said aperture and including a first drive housing and a second drive housing;

an outer shaft mounted on and inside said first drive housing by bearings;

an inner shaft within said outer shaft and concentric therewith and mounted on and inside said second drive housing by bearings;

a first rotor mounted on said outer shaft;

a second rotor mounted on said inner shaft;

a first stator mounted on and outside said first drive housing;

a second stator mounted on and outside said second drive housing;

a pilot bearing supporting said outer shaft upon said inner shaft; and

means for causing each of said stators to impress a suitable electromagnetic field upon its respective rotor so as to impart rotary motion thereto.

4. Apparatus for imparting rotary motion to a device within a vacuum chamber comprising in combination:

a vacuum-tight tubular casing of non-magnetic material, said casing having a longitudinal axis,

a first shaft rotatably mounted inside said casing along said axis, said first shaft having a first disk of magnetic material mounted thereon,

a second shaft rotatably mounted inside said casing about said first shaft, said second shaft being tubular and having a second disk of magnetic material mounted thereon outside said second shaft,

a first coil mounted outside said casing and adapted to generate a magnetic field in said first disk,

a second coil mounted outside said casing and adapted to generate a magnetic field in said second disk,

at least said first coil being adapted to generate a first rotating field pattern for rotating said first shaft, said first disk being magnetized in a pattern for being rotated by said first rotating field pattern.

5. Apparatus in accordance with claim 4, wherein said second coil is adapted to generate a second rotating field pattern for rotating said second shaft, and wherein said second disk is magnetized in a pattern for being rotated by said second rotating field pattern.

6. Apparatus in accordance with claim 4, wherein said first shaft has a third disk of magnetic material mounted thereon, wherein said second shaft has a fourth disk of magnetic material mounted thereon adjacent to said third disk, and wherein said casing has a fifth disk of magnetic material mounted thereon inside said casing adjacent to said second disk, said first coil being adapted to generate a field pattern for pressing said second disk and said fifth disk together for braking action coupling said second shaft to said first shaft, said apparatus also including a third coil mounted outside said casing and adapted to generate a magnetic field in said third disk and fourth disk for pressing said third disk and said fourth disk together for braking action coupling said second shaft to said casing.

7. Apparatus in accordance with claim 4, wherein a sensing mechanism is supported on and within said casing, and wherein a disk is affixed to said first shaft, said disk having a coded pattern adapted to activate said sensing mechanism.

8. Apparatus in accordance with claim 7, wherein a second sensing mechanism is supported on and within said casing, and wherein a second disk is affixed to said second shaft, said disk having a coded pattern adapted to activate said second sensing mechanism.

9. Apparatus in accordance with claim 7, wherein a light-emitting diode and a read head are supported on and within said casing, and wherein a disk is affixed to said first shaft, said disk having a coded pattern of opaque portions adapted to pass between said light-emitting diode and said read head.

10. Apparatus in accordance with claim 8, wherein a second light-emitting diode and a second read head are supported on and within said casing, and wherein a second disk is affixed to said second shaft, said disk having a coded pattern of opaque portions adapted to pass between said second light-emitting diode and said second read head.

11. Apparatus in accordance with claim 1, wherein said electromagnetic field is derived from one or more encoders mounted on one or both of said shafts.

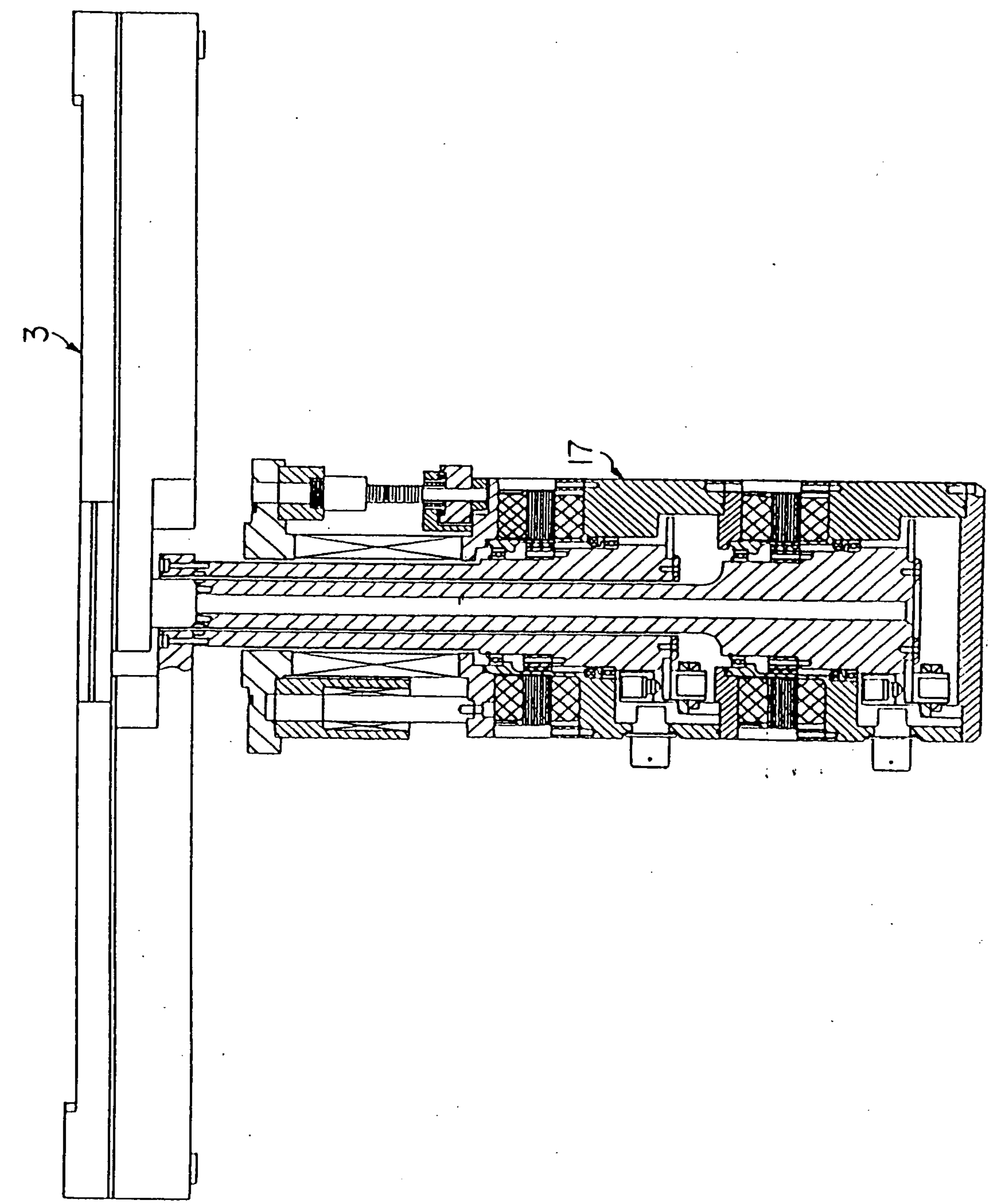


FIG. 1

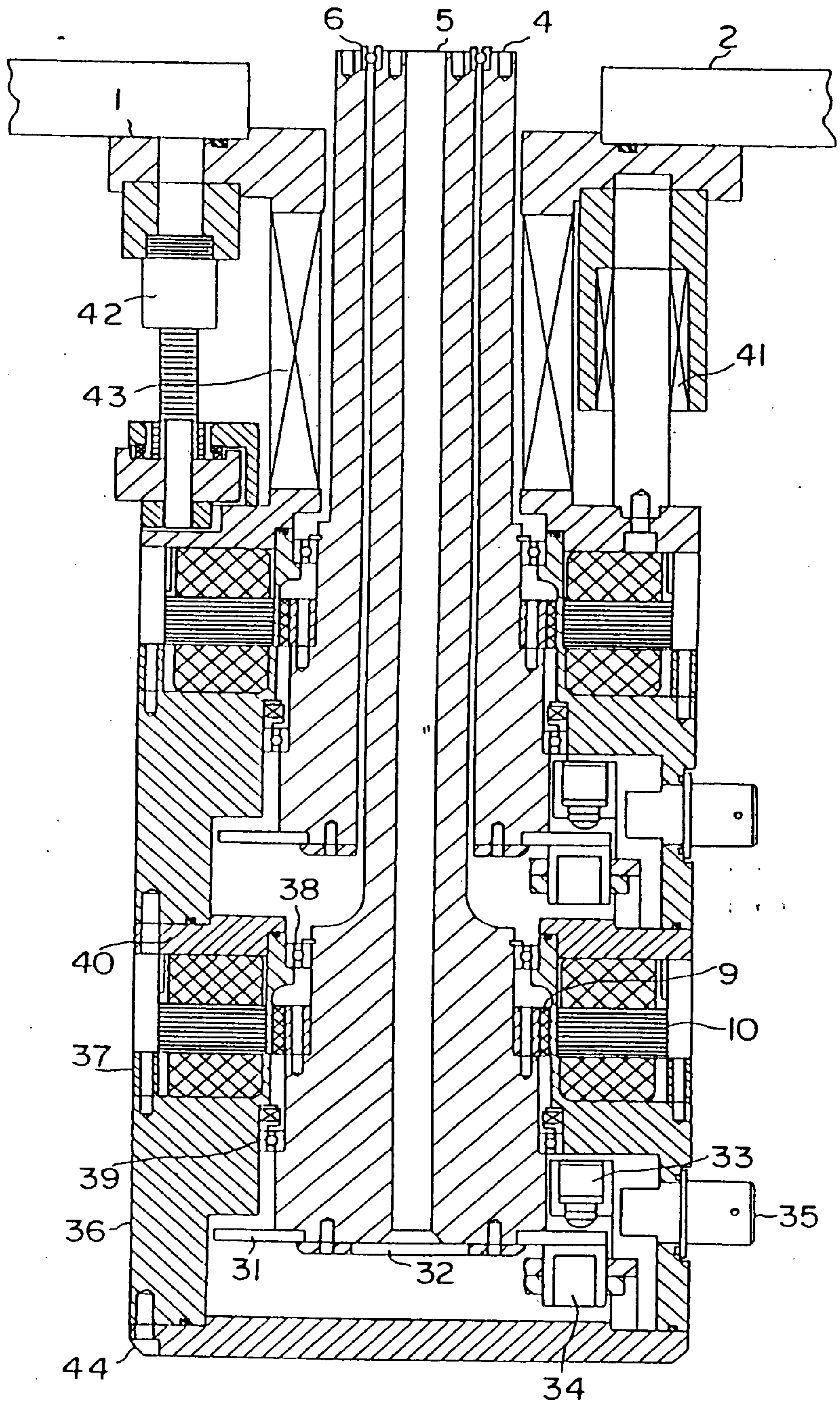


FIG. 2

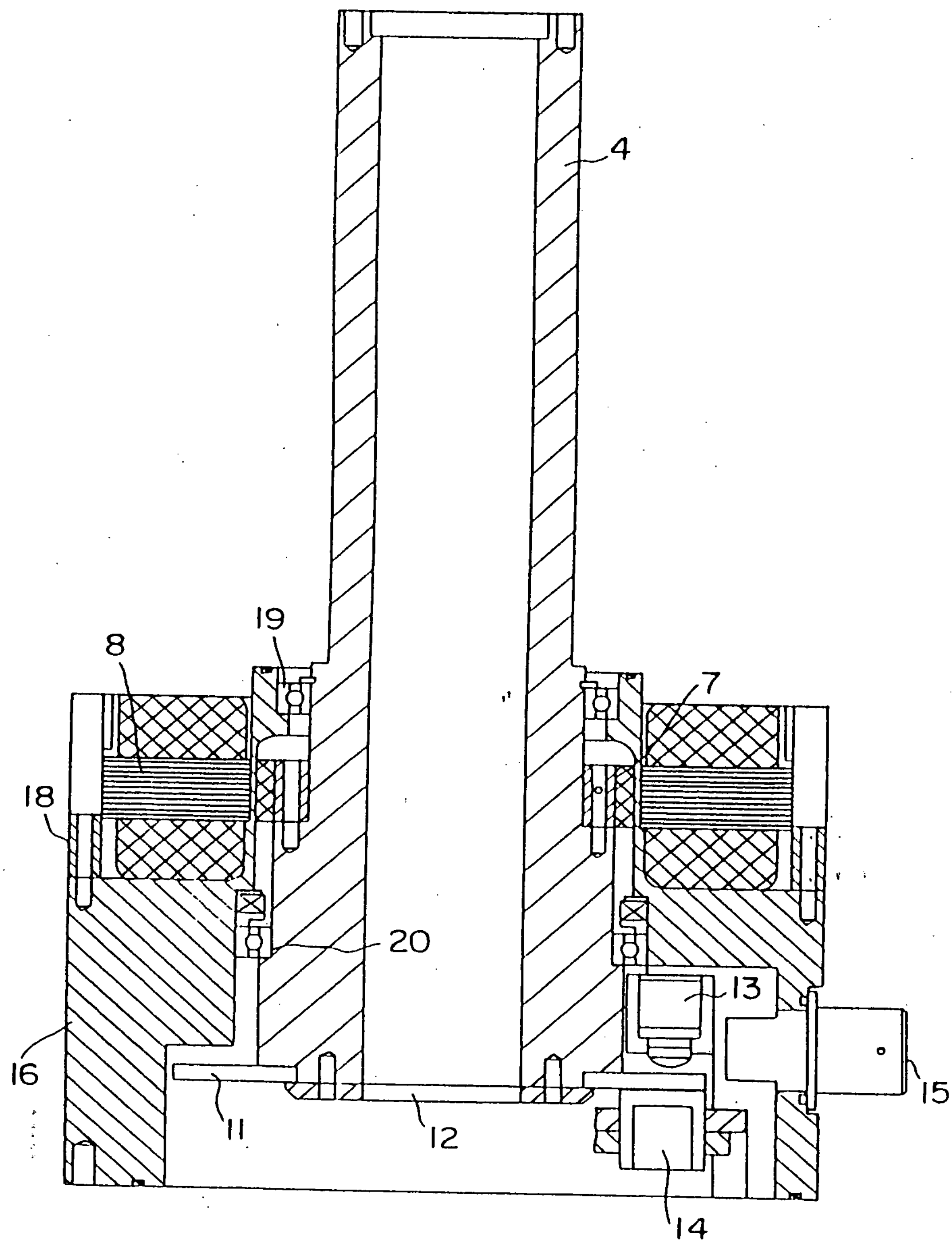


FIG. 3

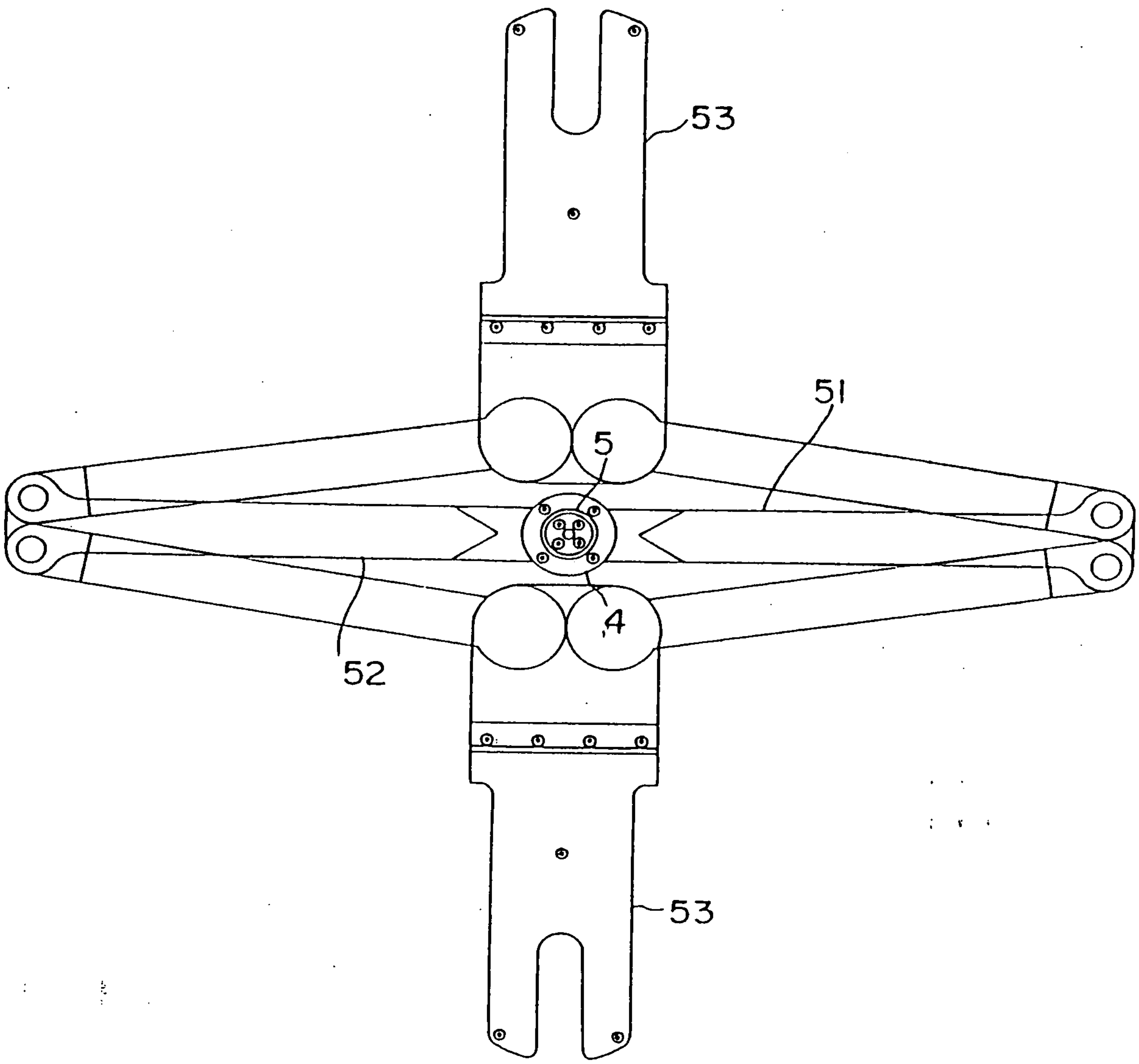


FIG.4

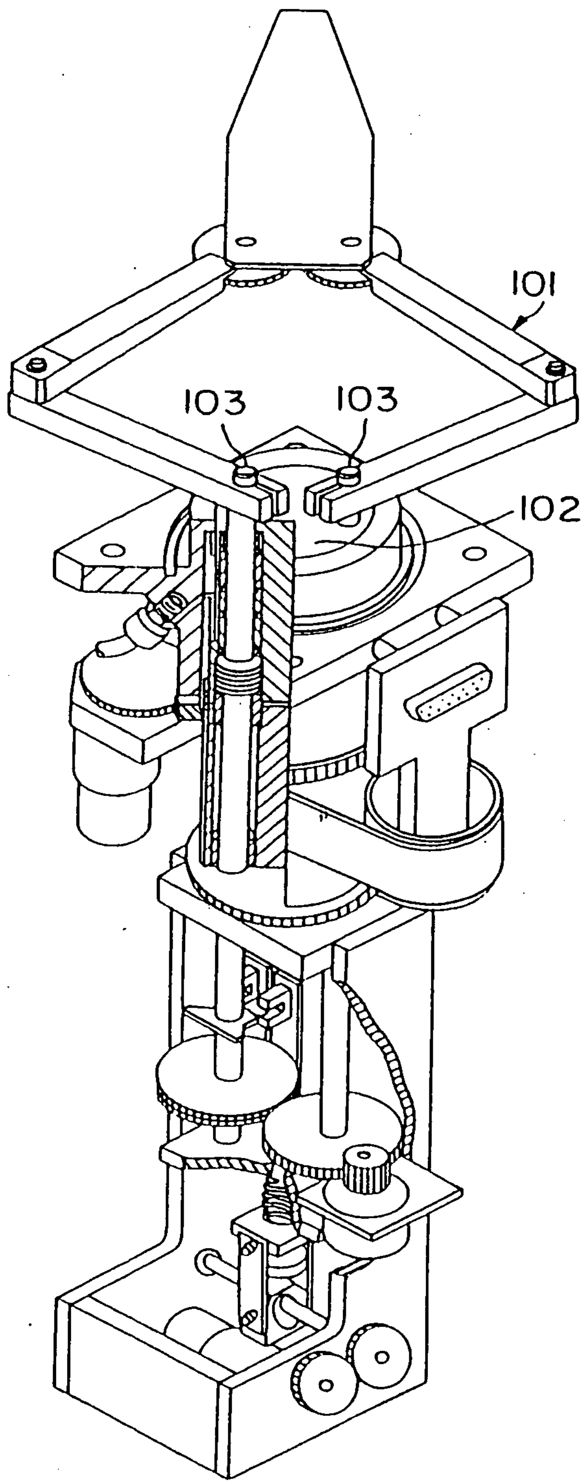


FIG.5
PRIOR ART

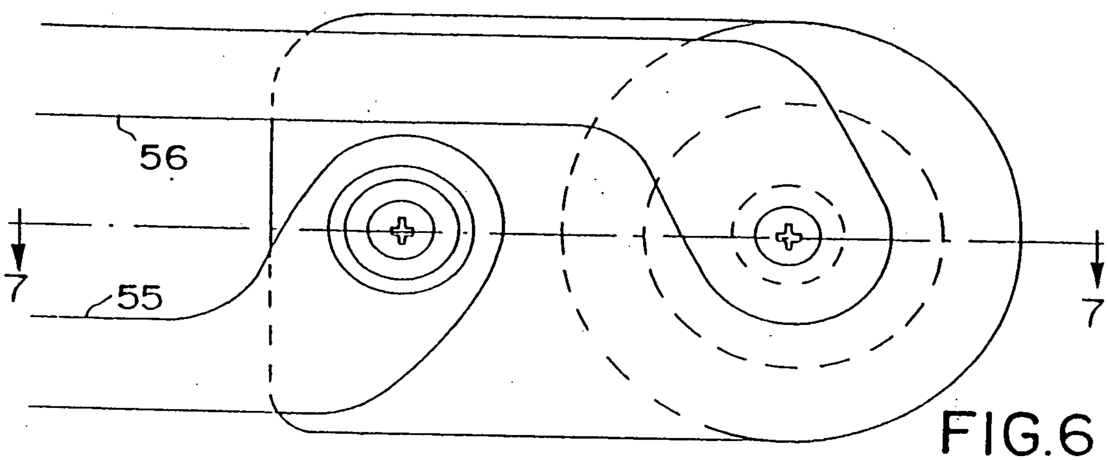


FIG.6

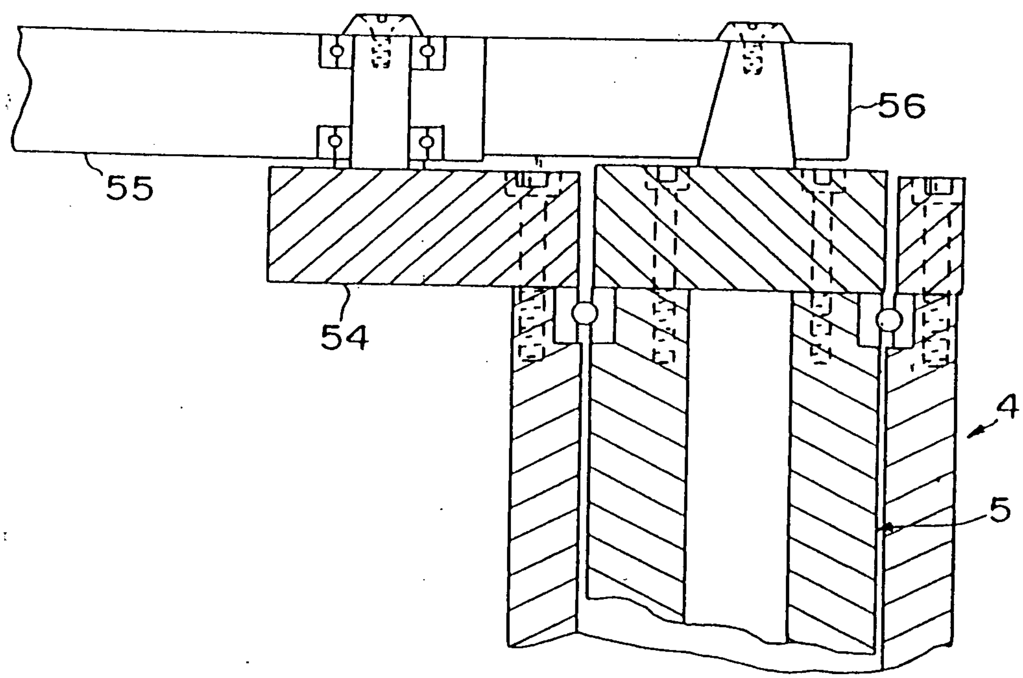


FIG.7

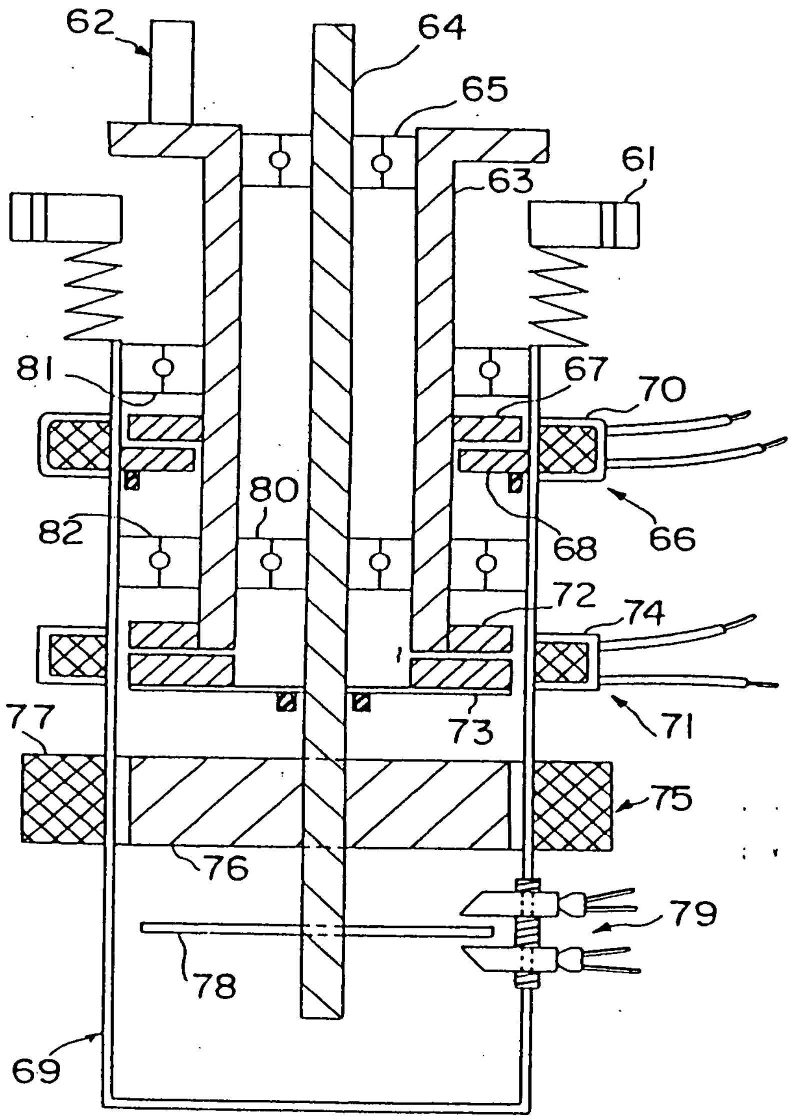


FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/04040

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B25J 21/00; H02K 16/00
US CL :414/744.5; 901/23; 310/114; 192/18B
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 414/744.5, 744.2; 901/15,23,24; 310/67R, 75D, 88, 101, 103, 112, 114; 192/18B, 12D; 74/479 BP

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

None

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US,A, 5,270,600 (Hashimoto) 14 December 1993, Figure 7	1,4,5,11 ----------- 2,3,7-10
Y	US,A, 5,180,276 (Hendrickson) 19 January 1993; Figure 1B	2,3
Y	US,A, 4,712,971 (Fyler) 15 December 1987	2,3
Y	JP,A, 2-292153 (Fuji Electric Co. Ltd.) 03 December 1990 Figures 12b (claim 2) and 9 (claim 3).	2,3
Y	US,A, 3,768,714 (Applequist) 30 October 1973 elements 156,160,166.	7-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of the international search 21 JUNE 1994	Date of mailing of the international search report 05 JUL 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Underwood Telephone No. (703) 308-1112